FACTORS CONTROLLING THE DISTRIBUTION OF EXOTIC PLANTS IN THE KO'OLAU MOUNTAINS, O'AHU

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A study of native and exotic plants was conducted in two rain forest communities in the Ko'olau Mountains, O'ahu. One study area is on Mt. Tantalus in the southern Ko'olau's; the other, 24 miles to the north, is at Pupukea. The study areas are between approximately 1500 and 2000 feet in elevation and are within the 'Ohi'a Vegetation Zone as described by Egler (1939). Eighteen 400 m^2 plots were sampled in the more natural vegetation of Tantalus, 16 such plots were placed at Pupukea. All species of vascular plants growing in the sample plots were recorded and their abundance estimated.

Of the 110 species of vascular plants found in the sample plots of either study area, 38 are exotic. Of these 38 exotic species, only a few are important in determining the structure and appearance of the vegetation. If frequent is taken to mean "occurring in at least half of the sample plots of one or the other study area," and abundant to mean "having cover greater than twenty percent in at least one sample plot," then only seven species of exotics are both frequent and abundant in these study areas. These seven are the trees: Psidium guajava, P. cattleianum, and Citharexylem spinosum; the smaller woody plants: Cordyline terminalis and Clidemia hirta; and the two grasses: Andropogon virginicus and Setaria palmaefolia. These species often dominate their respective vegetation layers and locally give the vegetation the appearance of being dominated by exotic plants.

Concern about the impact of exotic plants on Hawaiian ecosystems and the detrimental effects that these introductions may have on the endemic flora necessitates the examination of the ecology and behavior of exotic species and to ask the question "Why of the more than 4000 species of exotic plants found in Hawaii (St. John 1973) have these seven species become frequent and abundant in these rain forest communities?" Species which are obviously "trailside weeds," such as Erechtites hieracifolia, will not be discussed in detail, since any damage to the native vegetation associated with the presence of these plants can be more directly attributed to the disturbance that allowed them to become established. At the same time, it is not realistic to discuss these ecosystems under conditions of no human-induced disturbance. The presence of pigs and goats in the southern Ko'olau's, and at least occasional human presence throughout the

range insure that the vegetation will always be subjected to some disturbance. Exotic plants which can exploit this minimal level of disturbance are of prime interest.

The occurrence of 11 exotic species at Tantalus which do not occur at Pupukea supports the hypothesis that more exotics are found in the southern Ko'olau's because the effects of man are greater at that end of the range, especially in the Honolulu area, to which Mt. Tantalus is adjacent. This hypothesis proposes that the distribution of exotic plants is largely a function of seed availability and disturbance of the vegetation by man or recently introduced animals. Observations and research indicate that now, as well as in the past, the Tantalus study area is subjected to more disturbances of these kinds than is the Pupukea study area, and that Tantalus has available to it a greater source of potential exotic invaders in the form of ornamentals and other introduced plants grown in botanic and private gardens in the Honolulu area.

The presence of escaped cultivars on Tantalus, such as Cinnamomum zeylanicum and Ilex paraguariensis, and of the ornamentals Ardisia crispa and Tropaeolum majus, clearly indicates that proximity to Honolulu is a controlling factor of these species distributions. None of these exotic species are reported elsewhere in the Ko'olau's. Citharexylem caudatum was introduced into Lyon Arboretum in Manoa Valley at the foot of Mt. Tantalus. This tree now forms dense stands on Tantalus and elsewhere on the periphery of Manoa Valley and has been reported as "occasional" in the Schofied Barracks area (USACH, unpublished).

However, there are species of exotic plants which have distribution patterns that do not fit the hypothesis that the spread of exotics is mediated by man alone. There are exotics which are found in the Tantalus study area and near, but not in, the Pupukea study area; and exotics that occur at Pupukea and in the vicinity of, but not in, the Tantalus study area. These distribution patterns would not be found if seed availability were the only factor governing the distribution of exotic species.

The common guava, Psidium guajava, is the most abundant exotic tree on Tantalus, but only a few scattered individuals of this species occur in the Pupukea study area. Guava occurs on all sides of the Pupukea study area, indicating that unavailability of seeds is not the reason this species is not abundant there. The distribution of Schinus terebinthifolius is similar to that of the guava.

On the other hand, the noxious shrub Clidemia hirta, another melastomaceous weed, Pterolepis glomerata, and the grass Andropogon virginicus, are very common in the Pupukea study area and elsewhere in the Ko'olau's. These three exotics are found near Tantalus, but not in the Tantalus study area. Considering the great dispersability of the seeds of all three of these species, it is not possible that unavailability of seed is responsible for the absence of these three species on Tantalus.

With respect to the distribution of some exotic plants, it would appear that each study area is an island surrounded by these species, but free of them. Distribution patterns of some native plants coincide with these exclusive distributions of exotics. On Tantalus and at lower elevations in the Pupukea area, Acacia koa is a co-dominant in the 'ohi'a forest. Koa is lacking in the Pupukea study area. Metrosideros tremuloides is the most common species of the genus at Tantalus; only one individual of this species was found in the Pupukea study area. Many native species which are common at Pupukea are absent or of low frequency at Tantalus. These include Cibotium chamissoi, Alyxia olivaeformis, Scaevola gaudichaudiana, Wikstroemia oahuensis, Lycopodium cernuum, Pelea clusiaefolia, Clermontia oblongifolia, and Tetraplasandra pupukeensis.

These differences in the native and exotic floras of the two areas suggest that important environmental differences exist. According to published meteorological data (Voorhees 1929?; Taliaferro 1959), the annual amount and the monthly distribution of rainfall is quite similar in both areas. No major climatic differences exist.

Analyses of the soils of the sample plots of the study areas were conducted. The soil at Pupukea is mapped as the Kapaa Series (USDA 1972). These highly weathered clays are classified as Oxisols. They are derived from Ko'olau basalt and have a high gibbsite content. Analyses showed the mean pH to be 4.6. Available phosphorous was undetectable in most samples. Bases, especially calcium and magnesium, were present only in very low concentrations. All analyses indicated that the soils of the Pupukea study area are extremely infertile.

In the Tantalus study area, two very distinct soils were found. A majority of the study area is on cinder-derived soils of the Tantalus Series. This inceptisol is derived from ash and cinder of the Tantalus eruption (USDA 1972) which is dated to less than 100,000 years age (MacDonald & Abbott 1970). These soils are youthful and were found to retain higher concentrations of calcium and magnesium than the soils of Pupukea. Mean A horizon pH is 5.6 and available phosphorous was detected in all samples.

Several sample plots in the Tantalus study area were found to be on soils derived from the ancient Ko'olau basalt rather than Tantalus cinder. These highly weathered clays have a mean pH of 4.6 with no detectable available phosphorous or calcium in the A horizon. These lava-derived soils, like the lava-derived soils of Pupukea, are extremely infertile.

The influence of soil fertility on the vegetation structure and quantity of biomass supported at each study area can be seen. At Pupukea, the canopy above 2 m high is rarely more than 50% closed and above 5 m is approximately 70% closed. Thus, the forest at Pupukea can be called "open," while the canopy at

Tantalus is "closed" and of higher stature. While no measurement of biomass was made, it is evident that a larger standing crop is maintained on the more fertile cinder-derived soils of Tantalus than at Pupukea.

In some cases, the distribution of exotic species can be directly correlated with the canopy characteristics of the community. For example, shade-loving Setaria palmaefolia and Commelina diffusa are found on the forest floor of Tantalus. Neither species occurs in the open forest of the Pupukea study area. At Pupukea, Andropogon virginicus locally dominates the ground cover under the open tree canopy, but this grass is not found on Tantalus. The distributions of these and other species appear to be controlled by biotic characteristics of the ecosystems, and only secondarily by the environmental factors which determine the general structure of the community.

In other cases, the effect of environmental factors is directly expressed. The near absence of the common guava, Psidium guajava, from the Pupukea study area is not a result of seed unavailability, lack of vegetation disturbance, or an unsuitable vegetation structure. The most reasonable explanation is that this tree can not tolerate the stress of the acid, infertile soil of Pupukea. Similarly, Clidemia hirta is in the vicinity of Tantalus and has been shown to be relatively shade tolerant (Wester & Wood 1977) but it is not found in the Tantalus study area. This species is very tolerant of infertile soil but lacks the genetic attributes needed to compete with faster growing plants on a less stressful site. This tree appears to be both tolerant of soil infertility and capable of competing on more fertile sites.

That soil fertility is a controlling factor in the distribution of both native and exotic plants is supported by the finding that the vegetation of the infertile lava-derived soils of Tantalus is more like the vegetation of Pupukea than like that of the more fertile soils of Tantalus. The vegetation of these lava-derived soils of Tantalus exhibits an open canopy; lacks a number of species common in other Tantalus communities, such as Psidium guajava; and possesses several species common at Pupukea but rare elsewhere on Tantalus, such as Dicranopteris linearis.

In conclusion, it has been found that a number of exotic species have escaped cultivation into the native vegetation around Honolulu. Some of these do not appear to be aggressive; others, such as Citharexylem caudatum, do. Some exotic species, especially grasses and forbs, have distribution patterns determined by community biotic factors, such as degree of canopy cover. The distribution of other species is controlled by soil fertility.

It is suggested that the difference in soil fertility between the Tantalus and Pupukea study areas is one of several or many environmental barriers that can be found within a climatically similar zone of the Ko'olau Mountains. These barriers may effectively prevent the spread of an exotic species through the

native rain forest. However, the several exotic species that are capable of crossing all or most of these barriers are the plants that must be considered a threat to the integrity of native vegetation and to the existence of local endemics. From this study it has been found that the most threatening exotic plants in the rain forests of the Ko'olau Mountains are Psidium cattleianum, Citharexylem caudatum, and Clidemia hirta.

LITERATURE CITED

Egler, F. E. 1939. Vegetation zones of Oahu, Hawaii. Empire Forestry Journal 18(1): 1-14.

MacDonald, G. A., and A. T. Abbott. 1970. Volcanoes in the sea. Univ. Hawaii Press, Honolulu. 441 pp.

St. John, H. 1973. List and summary of the flowering plants in the Hawaiian Islands. Pac. Trop. Bot. Gdn. Mem. 1. 519 pp.

Taliaferro, W. J. 1959. Rainfall of the Hawaiian Islands. Hawaii Water Authority, Honolulu.

USACH. Installation environmental impact statements. Botanical Survey. United States Army Support Command, Hawaii. Held in Dept. of Botany, Univ. Hawaii. (Unpublished).

USDA Soil Conservation Service. 1972. Soil survey of the islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. U. S. Government Printing Office, Washington, D. C. 754 pp.

Voorhees, J. F. 1929? A quantitative study of the rainfall of the island of Oahu. Paradise of the Pacific, Honolulu.

Wester, L. L., and H. B. Wood. 1977. Koster's curse (Clidemia hirta), a weed pest in Hawaiian forests. Environmental Conservation 4(1): 35-42.